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HYBRID PV-WIND MICRO GRID MODELING AND ANALYSIS USING QUASI Z-SOURCE INVERTER

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Abstract

The purpose of this research is to model and regulate a micro-grid with a combination of PV and wind using a Quasi Z-source inverter (QZsi)[1]. The (QZsi) offers several benefits over typical inverters, including improved buck/boost characteristics, angle output phase adjustment, decreased harmonic substance, zero filters required, and high-performance capability. The study used the DC-DC converter using a single-ended primary inductance converter (SEPIC)[9] module switching power equipment to track the maximum power point (MPP) of the PV module[8]. A new version of the power ratio variable step is used in the proposed maximum power point tracking (MPPT) approach (MPRVS) focused on the perturb and observe (P&O)[6] approach, which successfully drives the pivotal point closer to the MPP. The suggested controller combines the battery-powered, PV-wind hybrid system with loads running in a variety of situations. The independent microgrid system is designed for rural applications. The study used a SEPIC module (single-ended primary inductance converter) as a DC-DC converter[10] to track the PV module's maximum power point (MPP). Switching power equipment. The suggested method using maximum power point tracking (MPPT) is a disturb and watch (P&O)[2] method based on step variable power ratio tweaked (MPRVS) that successfully drives the pivotal point closer to the MPP.

The suggested controller combines the battery-powered, PV-wind hybrid system with loads running in a variety of situations. The independent microgrid system is designed for rural applications.

Keywords: Photovoltaic (PV) , Single Ended Primary Inductance Converter, quasi Z-source inverter (SEPIC) , Power Ratio Modified Variable Step (MPRVS) , Maximum Power Point Tracking (MPPT) are some keywords.

INTRODUCTION

Cell and micro-hydro are seen as viable decentralised power generating solutions in microgrids. The incorporation of renewable energy sources into micro-grids has various advantages, including reduced greenhouse gas emissions, increased energy efficiency, improved energy security, and cost-effective power delivery. Yet, the variable and intermittent nature of renewable energy sources poses considerable challenges. Microgrid operation and control presents unique issues.

To address these issues, several control and management tactics, such as enhanced forecasting approaches, energy storage systems, demand-side management, and optimal power flow algorithms, have been developed. A micro-grid is a network of connected energy storage devices, active consumers, and other loads that use distributed energy resources (DER). It provides electricity to a tiny area.

Provides great dependability and can tolerate fluctuating loads. Conventional energy sources, such as nuclear power plants and fossil fuels, are not ecologically friendly and suffer from large power losses owing to long-distance communication. As a result, academics and enterprises have focused increasingly on renewable energy sources such as distributed generation (DG) sources like solar, wind, fuel cells, hydro, and tidal energy, and so on. These sources are adaptable, extendable, and eco-friendly. To be able to reach the maximum power point (MPP)[2], which enables the greatest amount of power extraction from renewable sources, MPPT, or maximum power point tracking, crucial requirement. Particle Swarm Optimization (PSO), Incremental Conductance (INC), Fuzzy Logic Control (FLC), Perturb & Observe (P&O)[7], Artificial Neural Network (ANN), Ant Colony Optimization (ACO), and Artificial Bee Colony (ABC), and Algorithm Firefly (FA)[1] are a few MPPT techniques that have been read through the literature, but they were unable to identify the worldwide high point in situations with some shade.. As a result, in this paper, we present a Modified Power Ratio Variable Step (MPRVS) approach based on the P&O technique[1] that does not need the use of a proportional-integral (PI) controller. As compared to a typical P&O algorithm, our technique lowers power oscillation around the MPP and protects battery charging from voltage fluctuations.

Quasi Z-Source inverters are used within a microgrid to prevent the occurrence of multi-reversal generation. A crucial interface for PV module peak power generation is the DC-DC converter. In this study, we use a SEPIC, or single-ended primary inductance converter offers higher voltage increase and improved buck/boost efficiency than existing dc-dc switching converters of power, to obtain high-quality tracking behaviour. We also employ a second DC-DC converter called a SEPIC converter since it has buck/boost capabilities. An inverter and a boost converter are combined in the QZsi. The MPP is provided by the SEPIC converter. accomplishment and successfully operates under various levels of solar insolation and wind speed, controls the MPRVS-based P&O MPPT. The SEPIC converter[1] also serves as a converter for impedance between the Z-source inverter and the PV panel.

In this research work, We use a a hybrid PV-wind microgrid system with a unofficial Z-source inverter to cut down on the number of reverse conversions and boost the micro-effectiveness. grid's In Section 2, we outline the whole architecture regarding the hybrid PV-Wind micro-grid setup, including models for PV generators, wind turbines, the MPPT algorithm based on MPRVS, SEPIC converter design requirements, battery models, and Inverter with a quasi-Z source modes of operation. In the experimental findings, which support the effectiveness of the suggested hybrid microgrid for PV and wind[1] power, are presented in Section 3.

The study paper's novelty comes from the fact that the advanced MPPT algorithm based on MPRVS has never been addressed or applied to an experimental a quasi Z-source inverter and a hybrid PV-wind microgrid. We have drawn from the body of literature already in existence to offer a fresh and effective approach to the production and distribution of renewable energy in a micro-grid system.

Fig 1 displays the proposed structure of a system of a micro grid[1] that combines PV and wind power. A wind turbine, a solar power system, a storage system, and topologies of electrical power converters make up the micro grid system. Given its greater energy production capability over model with a single diode, for the PV generator, analogous circuit with two diode models have employed to study the system. To generate electricity, a generator is attached to the rotor of the generator. While being a complex system, the wind turbine may be modelled reasonably easily by simulating aerodynamic power or torque depending on the properties within the turbine, such as the power coefficient's nondimensional curves. To counteract the stochastic variations of both the solar and wind electricity fed into the grid or load, a battery system is required. We briefly describe the modelling process used to create the main parts of suggested micro grid technology in this section.

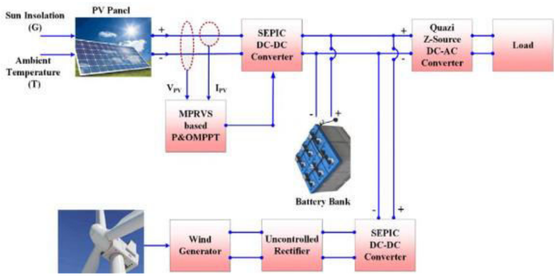

Fig 1: A block diagram showing the hybrid PV-wind micro grid system's structure.

Mathematical Model for Photovoltaic

A PV cell, which converts using solar energy electrical using power the photographic impact, typically consists of a Junction P-N diode made from a semiconductor substance like silicon. When sunlight enters the p-n junction, it excites the electrons in the semiconductor material, generating an electric current that depends on the intensity of the

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sunlight and the properties of the semiconductor.

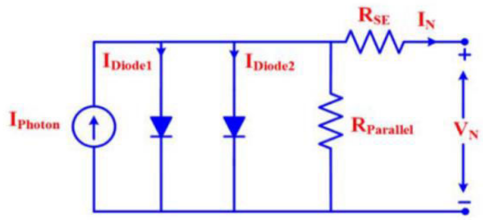

Fig 2: The equivalent photovoltaic (PV) cell circuit diagram can include parallel, series, and double diodes resistances.

The mathematical formula for the PV cell output current is :

$$I_N = I_{Photon} - I_{Diode1} - I_{Diode2} - \frac{V_N + I_N R_{SE}}{R_{Parallel}}$$

Moreover, the mathematical evaluation of photon current is :

$$I_{Photon} = [I_{Photon\_STC} + K_S(T_C - T_{STC})] \times \frac{G}{G_{STC}}$$

The formula for diode saturation current is :

$$I_{Diode1} = I_{Diode2} = \frac{I_{Short\_STC} + K_S(T_C - T_{STC})}{exp\frac{[(Vopen_{STC} + K_{VL}(T_C - T_{STC})}{V_{Thermal}} - 1}$$

Simulation of wind turbines :

An windmill is an apparatus that transforms the mechanical energy of the wind into electrical energy by way of a generator. A wind turbine's efficiency is influenced by a numerous factors, including wind speed, blade design, and blade pitch angle. The power coefficient (CPR), which compares the electricity generated by a wind turbine in comparison to the available in the breeze, gauges the effectiveness of a wind turbine[12].

The ratio of tip speed[12] (TSR) is another important factor that affects wind turbine performance. It represents the proportion of wind speed to blade tip speed and typically ranges from 6 to 8 for modern wind turbines.

The blade angle of pitch (BPA) is the inclination of the blade plane and the turbine's rotation plane. It is used to regulate the amount of power derived from the turbine.

To analyze the wind turbine's performance under different wind conditions, the power curve is plotted as CPR against TSR for different values of BPA. This curve provides useful insights into the wind turbine's performance and is a valuable tool for optimizing wind turbine design.

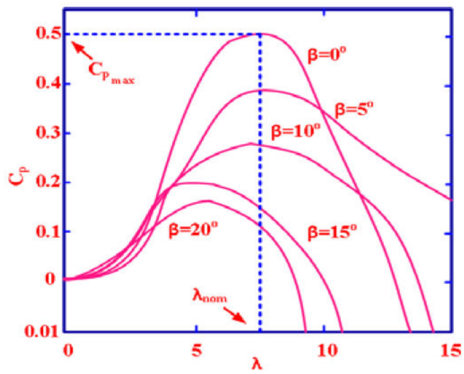

Fig 3: For various P.B, the CPR Tip speed and (performance coefficient) lT.S. curve is presented (Pitchblade angle). The wind turbine's ability to create mechanical

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power depends on the wind's velocity (VWind), turbine radius (RT), and coefficient of performance (CPR) (Performance coefficient).

$$P_{Mechanical} = \frac{1}{2} C_{PR} \pi R_T^2 \rho_{a,d} V_{Wind}^3$$

Moreover, a mathematical description of the ratio of tip speed (lT.S) that correlates with the blade's angular velocity (wA.V), VWind, and RT is also possible as

$$\lambda_{T.S} = \frac{\omega_{A.V} \times R_T}{V_{Wind}}$$

$$C_{PR(\lambda_{T.S},\beta_{P.B})} = 0.72[\frac{150}{\lambda_j} - 2 \times 10^{-3}\beta_{P.B} - 131$$
$$\times 10^{-1}]e^{\frac{-185\times10^{-3}}{\lambda_j}}$$

$$\frac{1}{\lambda_j} = \frac{1}{\lambda_{T.S} + 8 \times 10^{-2}\beta_{P.B}} - \frac{35 + 10^{-3}}{1 + \beta_{P.B}^3}$$

$$\lambda_{T.S} = \frac{\omega_G \times R_T}{V_{Wind} + \square_{gear}}$$

$$\square_{gear} = \frac{\omega_{GM} + R_T}{\lambda_{T.S} V_{Wind}}$$

SEPIC Converter Model

In a SEPIC converter, the input voltage can be higher, lower, or equal to the output voltage, and the output voltage can be positive or negative. The converter consists of a capacitor, an inductor, two diodes, and a switch.

During operation, On and off cycles of the switch occur at a particular frequency. causing the inductor to charge and discharge, which generates a voltage across the capacitor. The diodes ensure that the inductor and capacitor are properly charged and discharged, and the output voltage is regulated by controlling the duty cycle of the switch.

The SEPIC converter has several advantages over other types of DC-DC converters. It can provide a higher voltage gain than a standard boost converter, and it can handle a wider range of input voltages. Additionally, the SEPIC converter provides good voltage regulation, low output ripple, and high efficiency.

Overall, It is a SEPIC converter versatile and efficient Converting DC to DC that can be used in a variety of applications, including solar power systems, battery chargers, and LED drivers.

$$V_{output} = V_{supply} \times \frac{D_{duty}}{1 - D_{duty}}$$

$$L_A = \frac{V_{supply} \times D_{duty}}{\Delta I_{LA} \times f_{switching}}$$

$$L_B = \frac{V_{supply} \times D_{duty}}{\Delta I_{LB} \times f_{switching}}$$

$$C_A = \frac{V_{output} \times D_{duty}}{R_{Load} \times \Delta V_0 \times f_{switching}}$$

$$C_B = \frac{V_{output} \times D_{duty}}{R_{Load} \times \Delta V_0 \times f_{switching}}$$

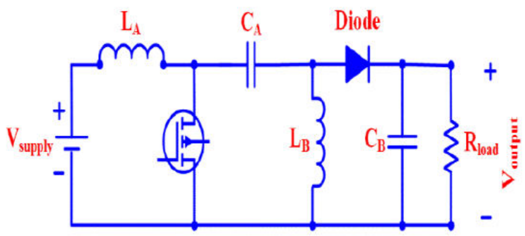

Fig 4: SEPIC converter equivalent circuit.

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Table 1 : SEPIC converter parameter.

Sl. No.	Parameters	Value
1.	Inductors ($L_A = L_B$)	0.42 mH
2.	Capacitors ($C_A = C_B$)	3.5×10^{-3} µF
3.	Current ripple ($\Delta I_{L_A} = \Delta I_{L_B}$)	0.5 A
4.	Voltage ripple (ΔV_0)	1×10^{-3} V
5.	Switching frequency ($f_{switching}$)	20 Hz

MODELLING OF P&O MPPT

The P&O (Perturb and Observe) approach based on MPRVS (Modified Perturb and Observe) is a control mechanism used to harvest the most electricity from solar panels. The gating pulses to the SEPIC (Single-EndedPrimary-Inductor Converter) converter are generated without the need of a PI (Proportional-Integral) controller in this approach. This reduces power fluctuation around the Power Point Maximum (MPP) and allows the operational stance to remain closer to the MPP, resulting in enhanced power extraction efficiency. The MPRVS-based P&O technology also prevents overvoltage in the battery charging system by adjusting the frequency of the SEPIC to convert manage the voltage produced. The instantaneous power received at the SEPIC output terminal through PVG (Photovoltaic Generator) is then utilised to alter the battery's duty cycle SEPIC converter in real-time to maintain maximum strength extraction from the solar modules.

Overall, the P&O with MPRVS approach using SEPIC converter control provides a dependable and effective solution for maximising power from solar panels while limiting battery charging system overvoltage.

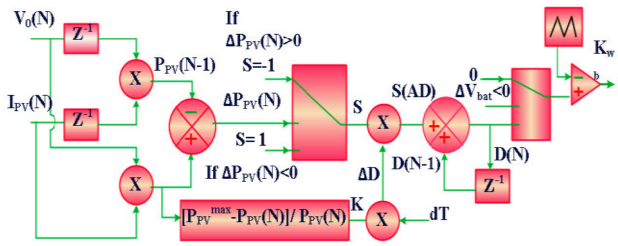


Fig 5: Working model of MPRVS based P&O technique.

$$P_{PV}(N) = V_0(N) \times I_{PV}(N)$$

$$P_{PV}(N-1) = V_{PV}(N-1) \times I_{PV}(N-1)$$

And if

$$\Delta P_{PV}(N) = P_{PV}(N) - P_{PV}(N-1) > 0, S = -1$$

$$\& P_{PV}(N) - P_{PV}(N-1) < 0, S = +1$$

$$D(N) = D(N-1) + S \times \Delta D$$

DD = Step changes in the duty ratio

= K X dT

dT = Fixed step size

K = Variable power ratio

$$K = \frac{P_{PV}^{max} - P_{PV}(N)}{P_{PV}(N)}$$

Modeling of the Quasi Z-Source Inverter:

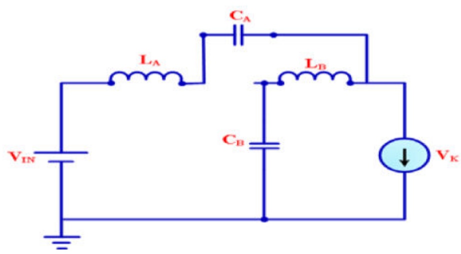


Fig 6: Quasi Z-source inverter equivalent model in the situation of shoot through.

$$V_{LA} = \left[\frac{(V_{IN} + V_{CB})T_A + (V_{IN} - V_{CA})T_B}{T_S}\right] = 0$$

$$V_{LB} = \left[\frac{V_{CA}T_A + (-V_{CB})T_B}{T_S}\right] = 0$$

The voltage of the capacitors (VCA&VCB) is computed scientifically by solving the aforementioned equations as :

$$V_{CA} = \left(\frac{T_B}{T_B - T_A}\right) \times V_{IN}$$

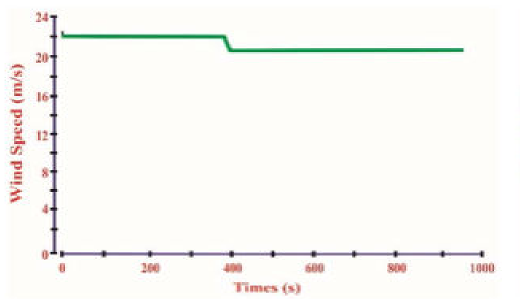
$$V_{CB} = \left(\frac{T_A}{T_B - T_A}\right) \times V_{IN}$$

DC-link voltage at its maximum = $V_{C_A} + V_{C_B}$

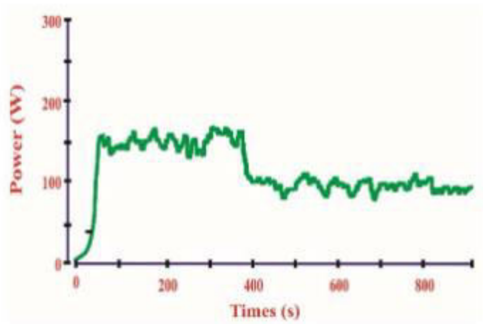
Maximum DC-link voltage = $\left|\frac{1}{1-2\frac{T_A}{T_S}}\right| V_{IN}$

$$= K \times V_{IN}$$

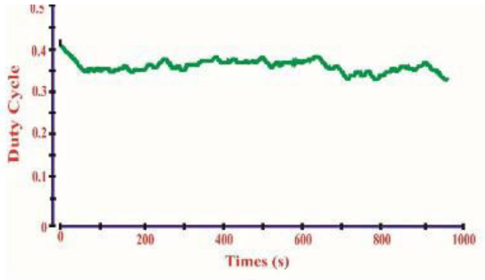
Results:



(a)



(b)



(c)

Fig 7: a) b) c) shows the results of an experiment with wind speed, wind power, and Cuk converter duty cycle.

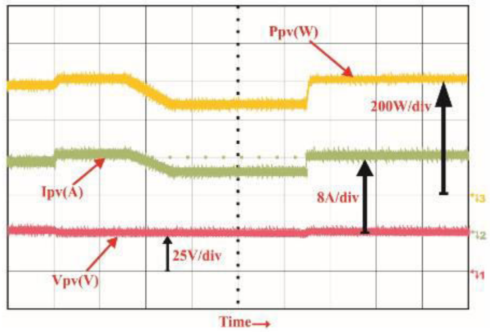
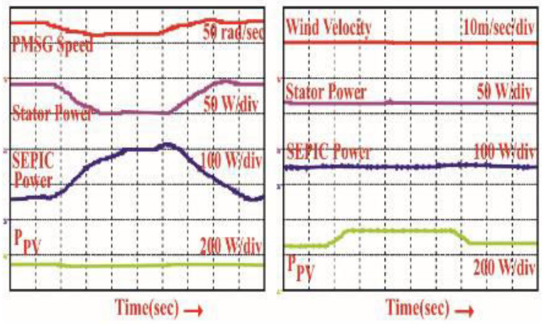


Fig 8: Responses of PV systems to abrupt variations in solar irradiance



(a) (b)

Fig 9: (a) The suggested hybrid micro grid's capability with various winds speed sun radiation that is constant **(b)** The hybrid micro grid's behaviour reacts under constant wind and variable solar radiation speed.

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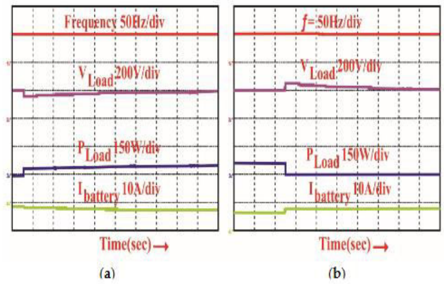

Fig 10: The hybrid micro grid's effectiveness under conditions of load reduction and load elimination.

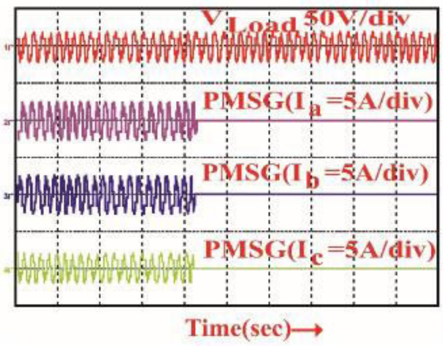

Fig 11: When operational conditions from the micro grid are disconnected, the wind generator's performance is assessed.

Conclusions:

The quasi Z-source inverter-based hybrid PV-wind microgrid is a promising solution for meeting the energy demands of remote areas or small communities. This project has demonstrated the feasibility and effectiveness of using renewable energy sources in combination with energy storage systems to create a reliable and sustainable power system.

The quasis Z-source inverter has been shown to be an efficient and cost-effective solution for integrating renewable energy sources into microgrids, while providing stable voltage and power quality. The use of this technology can also reduce the overall cost of the system by minimizing the need for external components such as transformers and filters.

Future Scope:

Future research is to develop better energy storage systems that can store renewable energy more efficiently and provide greater reliability. This can be achieved through the development of advanced battery technologies, such as flow batteries or solid-state batteries, that can provide longer cycle life and higher energy density.

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